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The Full Aperture Backscatter Station Measurement System on the National Ignition Facility*

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A Full Aperture Backscatter Station (FABS) target diagnostic has been activated on the first four beams of the National Ignition Facility (NIF). Backscattered light from the target propagates back down the beam path into the FABS diagnostic system. FABS measures both stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) with a suite of measurement instruments. Digital cameras and spectrometers record spectrally resolved energy for both P and S polarized light. Streaked spectrometers measure the spectral and temporal behavior of the backscattered light. Calorimeters and fast photodetectors measure the integrated energy and temporal behavior of the light, respectively. This paper provides an overview of the FABS measurements system and detailed descriptions of the diagnostic instruments and the optical path.

I. OVERVIEW

A Full Aperture Backscatter Station (FABS) target diagnostic has been activated on the National Ignition Facility (NIF) and measures both stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) on the first four NIF beams designated Q31B.¹⁻³

Backscatter measurements at NIF are important to understand key physics issues and to monitor laser performance. Backscattered light reduces the energy available for ignition. High power backscattered light has the potential to damage the laser system. Backscattered light measurements are also a basic tool used to provide insight into Laser-Plasma Interactions.

The majority of the backscattered light from a laser-produced target is directed back to the source port. FABS measures this light scattered back into the “full aperture” of the laser beam. FABS measures ion wave stimulated Brillouin scattering (SBS) over the wavelength range of 348nm to

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354nm, and electron wave stimulated Raman scattering (SRS) over the wavelength range of 400nm to 700nm. Backscattered light hitting the surrounding area of the port is measured by the Near Backscatter Imager (NBI) diagnostic that is currently being activated on the NIF.

The FABS measurement system is located inside a walled enclosure at the -33 foot level of the NIF target area. The enclosure provides a safety barrier around the FABS system and limits access to trained personnel who operate the diagnostic. All work on FABS is conducted following NIF guidelines and safety protocols. Work procedures include controls for the primary hazards including oxygen deficiency (due to argon filled beam paths directly above FABS) and NIF laser light sources.

II. OPTICAL PATH

The NIF is a very large laser system that starts with a low energy 1053nm pulse that propagates through a series of amplifiers, spatial filters, and turning mirrors to create high power 1053nm laser pulses propagating down each beam path toward the target chamber. As each laser pulse approaches the target chamber it reaches the last turning mirror that is specially coated to reflect 1053nm light and to transmit shorter wavelengths. The incident laser pulse reflects off the last turning mirror and enters the final optics assembly (FOA) where it is converted into 3ω light and focused on the target at Target Chamber Center (TCC). There are several optical components within the FOA (including frequency conversion crystals, diffraction gratings, lens, debris shields, beam smooth phase plates, etc.) that can produce low energy reflections at 1ω , 2ω , and 3ω that can propagate back down the FABS beam line.

FABS measures the SBS and SRS light backscattered from the target into each beam line passing through the turning mirror and into the FABS enclosure. Figure 1 shows the optical path of the laser light and backscattered light. An uncoated transport mirror reflects 3% of the light to a highly reflective spherical mirror, and then to dichroic beam splitter that separates the SBS and SRS components. The SBS light is reflected by the dichroic beam splitter while the SRS light passes through the splitter to similar suites of diagnostics. Each of the SBS and SRS converging beam paths include a set of large filter wheels, a beam block for ghost images from the FOA, and a transmission scatter plate that is viewed by optical fibers coupled to the calibration and streaked spectrometers. Beam splitters pick off weak reflections that are measured by calorimeters, fast photodiodes, and near-field speckle cameras.

III. EQUIPMENT

The FABS diagnostic system provides a complementary set of SBS and SRS backscatter measurements on all four NIF beams for each target shot. Figure 2 shows examples of data measured by FABS detectors.

Absolute SBS and SRS energy measurements are made using time-integrated “calibration” spectrometers coupled to wide dynamic range, high sensitivity Finger Lakes CM7 CCD cameras.⁴ The spectral images measure P and S polarized light separately on all four beams. The spectrally resolved measurements provide a method to remove errors due to spectral response variations in the beam line optics and unwanted reflections in the laser system. A novel method using an absolutely calibrated, 300W Oriel Model 6258 xenon arc lamp placed at target chamber center and an increased exposure time on the calibration spectrometer provides an absolute calibration of this diagnostic.⁵ This method is described in greater detail in Ref. [1].

A complementary energy measurement is made using Molectron J50LP-2A pyroelectric calorimeters.⁶ The calorimeters have been configured to reduce the contribution due to stray light and for ease of operation in changing ND filters. A P polarizer is placed in front of each calorimeter to reject any S polarized light. A metal cylinder in front of each calorimeter helps to reduce stray light, and ND filters can be added to optimize expected backscatter signal levels.

FABS also have SBS and SRS streaked spectrometers with nominally 100ps temporal resolution and 0.08 and 2.5nm spectral resolution, respectively. Hamamatsu C7700 streak cameras are currently used and only one beam line (B318) is measured by the streak spectrometers.⁷ Plans to multiplex several beams to each streaked system have been considered. Fast Hamamatsu R1328U-53 photodiode detectors are fielded on all four SBS beams providing a complementary time-resolved (≈ 150 ps) measurement of the backscatter.⁸

Spatially resolved near field speckle images are recorded on all four SBS beams using Finger Lakes CM7 CCD cameras. A gated CidTec ICID3710DX10 CCD camera will be used to measure the SRS speckle image from at least one beam line (B318).⁹ This detector is currently being tested as part of FABS.

IV. SOFTWARE

Control software has been implemented to run the FABS measurement equipment including the speckle cameras, calibration spectrometer cameras, calorimeter scopes, and fast photodiode scope. The software runs on a personal computer in a rack outside the FABS enclosure. The FABS shot operator sequences the FABS control software remotely over NIF ICCS network from the NIF control room. A data analysis tool called “Quick Look” has been developed to provide a prompt presentation and analysis of HDF5 formatted shot data from FABS and other Target Diagnostics.¹⁰

V. FUTURE PLANS

The first FABS diagnostic system on NIF has been activated and has provided important Target Diagnostic and laser data on all NIF Target Shots. Three lower level locations and one upper level location have been identified as future FABS systems. Planning has begun for the next NIF FABS designated Q36B. Figure 3 shows the current FABS location and three possible future FABS locations.

- [1] R. Kirkwood et al., these proceedings.
- [2] D. H. Foula et al., these proceedings.
- [3] S. H. Glenzer et al., in The Third International Conference on Inertial Fusion Sciences and Applications (Monterey, CA 2004)
- [4] Finger Lakes CM7 CCD camera, Finger Lakes Instrumentation, Lima, NY 14485 USA
- [5] Oriel Model 6258 Xe arc lamp, Thermo-Oriel, Spectra-Physics, Stratford, CT 06615 USA
- [6] Molelectron J50LP-2A pyroelectric calorimeter, Coherent-Molelectron, Santa Clara, CA 95054 USA
- [7] Hamamatsu C7700 streak camera, Hamamatsu Photonics, K.K., Japan
- [8] Hamamatsu R1328U-53 photodiode detector, Hamamatsu Photonics, K.K., Japan
- [9] CidTec ICID3710DX10, Spectra-Physics, Stratford, CT 06615 USA
- [10] Hierarchical Data Format (HDF), The National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign

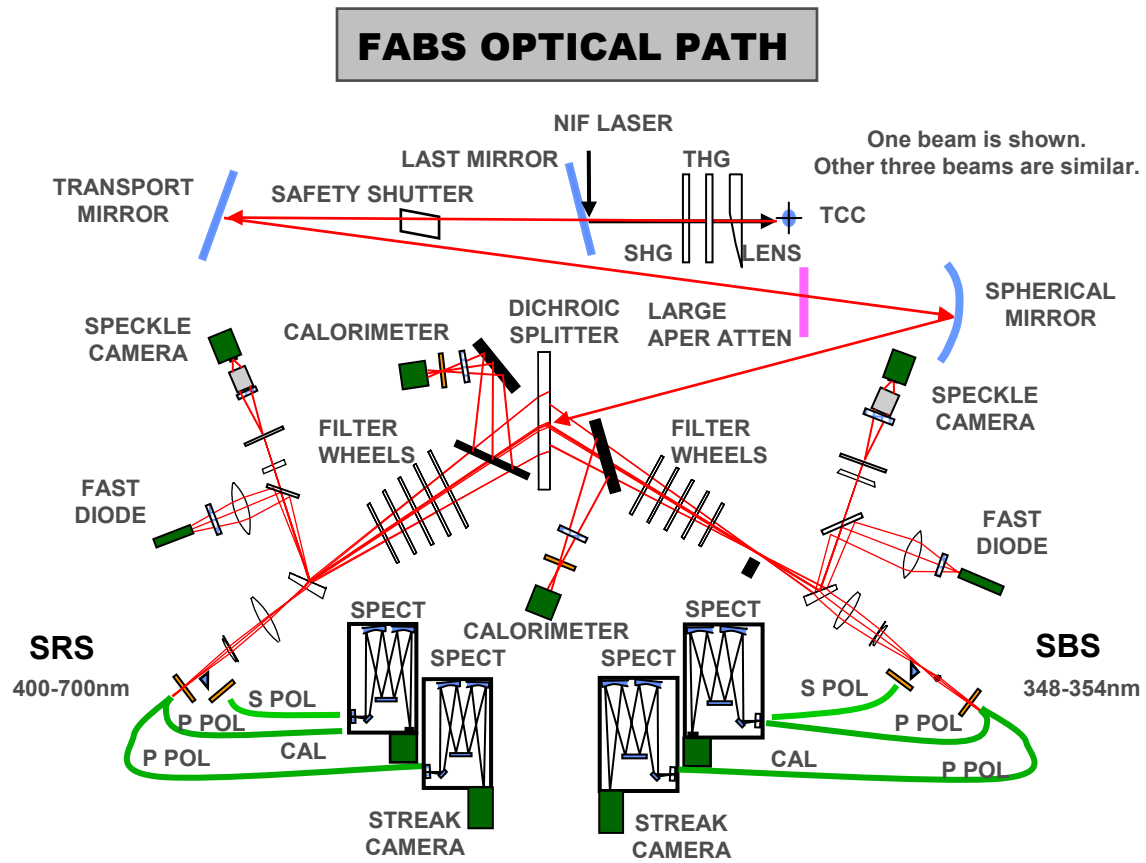
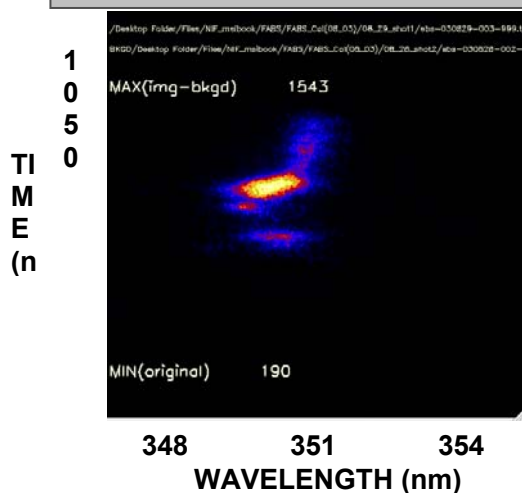


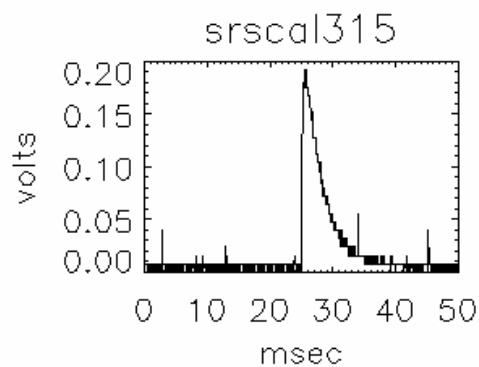
FIG. 1: The optical path from the last turning mirror to the target and back down to FABS is shown.

FABS SHOT DATA

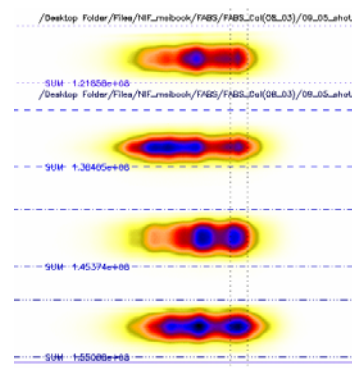
SBS STREAKED SPECTROMETER C5H12 GAS BAG



SRS CALORIMETER



SRS CALIBRATION SPECTROMETER



SBS SPECKLE IMAGE

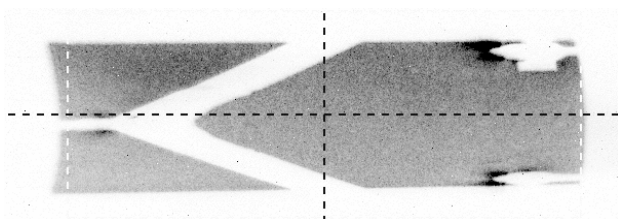


FIG. 2: Examples of data measured by FABS detectors is shown.

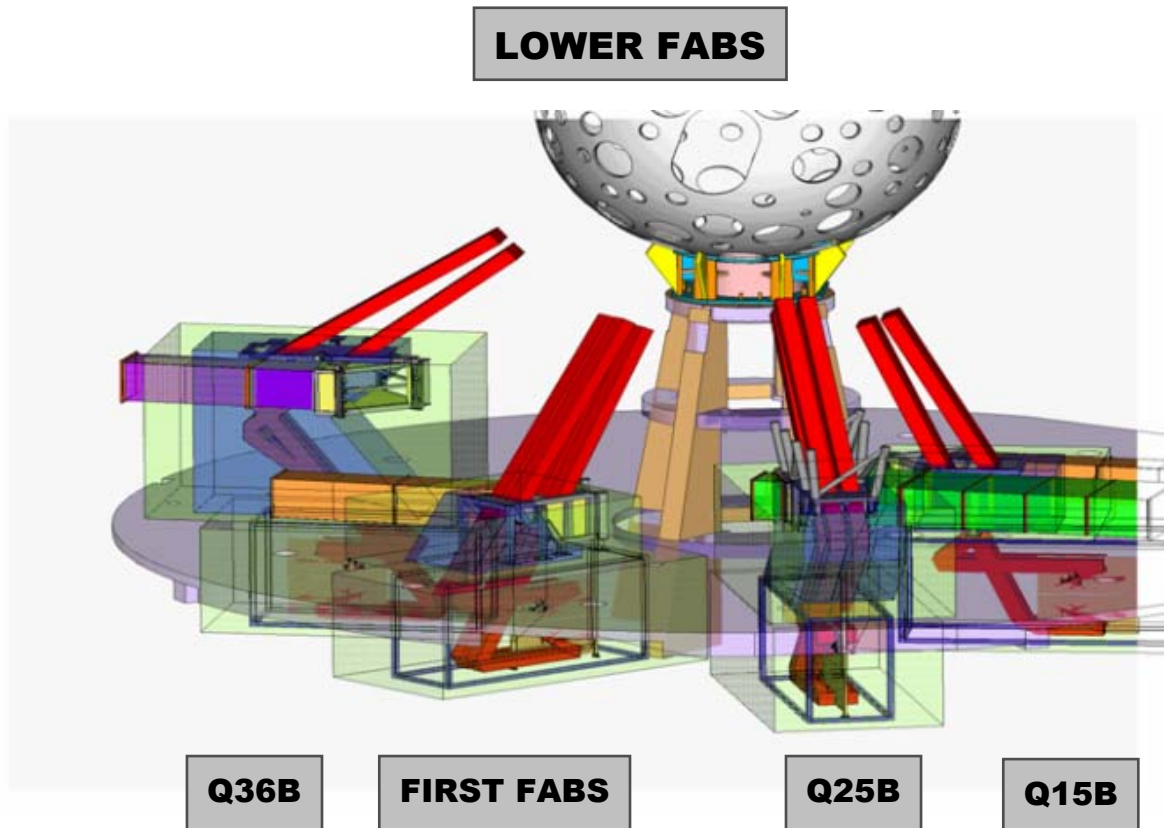


FIG. 3: The current FABS location and three possible future FABS locations are shown.